Numerical Weather Prediction

Comparison of (A)ATSR SST anomalies with other SST datasets

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Executive summary

Global retrievals of sea surface temperature (SST) have been made from the Along-Track Scanning Radiometer (ATSR) series of instruments from 1995 to 2004. In order to analyse any possible trends in the global SST throughout the period, daily anomalies are computed using a 61to90 daily climatology, averaged into global monthly means, and plotted as a global time-series. In order to evaluate these (A)ATSR anomalies, SST anomalies from other SST datasets have been computed and compared on the same timeseries. Global infra-red satellite SST data have been received from the Advanced Very High Resolution Radiometer (AVHRR) series, tropical microwave SST data from the Tropical Rainfall Monitoring Mission (TRMM) Microwave Imager (TMI), and global microwave SST data from the Advanced Microwave Sounding Radiometer (AMSR-E) on AQUA. Additionally the anomalies have also been compared with HadISST1 anomalies: HadISST is a globally complete 1-degree SST analysis compiled from in situ and AVHRR SSTs at the Hadley Centre.

Results indicate that the ATSR-2 D3 SSTs are optimally bias-corrected, whilst the AATSR D3 SSTs may be a little over bias-corrected, and thus too cool. Concerns have arisen over the quality of the AMSR-E SSTs due to an obvious lag in anomaly pattern behind the other SST sources indicating that more confidence should be given to the infra-red derived SSTs than the microwave SSTs. It is difficult without the addition of ATSR-1 SST anomaly data from 1991-1995 to assess the possibility of any trends in the data, although the time-series indicate the possibility of warming trends between 0.1-0.2K per decade. The time-series presented in this report will be updated with ATSR-1 data from 1991-1995 on receipt of the data from the Rutherford Appleton Laboratory when processing has taken place.

1. Introduction

Sea surface temperature (SST) is an important parameter in climate monitoring, being a huge, slow releasing storage of heat. Traditional attempts at monitoring global SST trends are performed using in situ ship and buoy SST data. However there are many problems with this method including sparse observations of in situ SST observations in some global regions, especially in the southern oceans. Additionally, measurements of SST using drifting, moored buoys and ship observations all employ different measurement methods including observing at different depths causing the SST record to be inconsistent. The advantage of using measurements of SST from satellite observations are the production of high-quality, consistent SSTs over a global coverage. This paper attempts to monitor global SST changes using various satellite data sources over the past 20 years, but in particular since 1995.

Global retrievals of SST have been made from the Along-Track Scanning Radiometer (ATSR) series of instruments from 1991 to the present. In order to analyse any possible trends in the global SST throughout the period, daily anomalies are computed using a 61to90 daily climatology, averaged into global monthly means, and plotted as a global time-series. In order to evaluate these (A)ATSR anomalies, SST anomalies from other SST datasets have been computed and compared on the same time-series. Global infra-red satellite SST data have been received from the Advanced Very High Resolution Radiometer (AVHRR) series, tropical microwave SST data from the Tropical Rainfall Monitoring Mission (TRMM) Microwave Imager (TMI), and global microwave SST data from the Advanced Microwave Sounding Radiometer (AMSR-E) on AQUA. Additionally the anomalies have also been compared with HadISST1 anomalies: HadISST is a globally complete 1-degree SST analysis compiled from in situ and AVHRR SSTs at the Hadley Centre. A further study of ATSR-1 and ATSR-2 SST anomalies using Averaged SST (ASST) data is given in Lawrence et. al, 2004. ASST data supplies a pre-retrieved skin SST at 0.5 degrees resolution. However, the (A)ATSR data used within this report is Cloud-Screened Consolidated Averaged Brightness Temperature data (CSCABT), allowing control over the retrieval of skin SST and at a higher spatial resolution at 1/6 degree (10 arc minutes).

2. Description of SST datasets

2.1 Along Track Scanning Radiometer measurements

The Along Track Scanning Radiometer (ATSR) has to date been flown on three satellite missions, ATSR-1 on ERS-1 (1991-1995), ATSR-2 on ERS-2 (1995-present) and the Advanced Along Track Scanning Radiometer (AATSR) on Envisat (2002-present). Each instrument has 3 infrared channels centred in the atmospheric windows at 3.7μm, 10.8μm and 12μm plus channels in the visible/infrared part of the spectrum used for cloud detection. The ATSR series of instruments are designed to retrieve SST to better than 0.3K accuracy in the derived skin SST and give a long-term stability of better than 0.1K.

ATSR has an inclined conical scan which enables it to make observations of the surface from two different angles, nadir and a forward view (~55°), within a few minutes of each other, allowing better correction for atmospheric absorption and aerosol than AVHRR, producing highly accurate SST retrievals.

In this report 2 types of dual-view ATSR skin SST retrievals are used: those using all 3 infrared channels (hereafter D3) during the night-only due to the solar contribution to the 3.7μm channel during the day, and retrievals using just the 10.8μm and 12μm channels (hereafter D2) during both day and night. Results are presented for ATSR-2 SSTs from 1995 to 2000 and then AATSR SSTs from 2002-2004.

The (A)ATSR skin SSTs have been processed to a pseudo bulk SST, which is the temperature of the ocean at around 1 metre in depth, using the Fairall model (Fairall et al, 1996) and is necessary because the satellite observes a radiative skin temperature which is always cooler than the sub-skin by more than 0.1K. For obtaining SST for climate purposes we require the bulk temperature which provides a more comparable measurement when looking at other climate datasets, and is more representative of the overall heat capacity of the ocean. More information on the processing of (A)ATSR skin SSTs to bulk SSTs is contained in O'Carroll et. al, 2003 and O'Carroll et. al, 2004.

2.2 Advanced Very High Resolution Radiometer measurements

AVHRR has an instantaneous field of view of 1.1km which scans across the swath perpendicular to the ground track of the satellite, whose orbit is sun-synchronous. It has two visible channels at 0.6 and 0.9μm, one short-wavelength infrared channel at 3.7μm and two long-wavelength infrared channels at 11 and 12m respectively. From the 3.7, 11 and 12μm channels, brightness temperatures can be inferred which are used to calculate SST (Pichel, 1991). AVHRR measures top-of-the-atmosphere radiances and then SSTs are retrieved using algorithms which have been tuned by regression of brightness temperatures from the instrument's infrared channels onto in situ SST data from a set of drifting buoys. Therefore, AVHRR SSTs are equivalent to measurements of the bulk surface temperature of the sea.

The AVHRR SST data used for this report, are un-bias corrected, and takes the form of monthly means of night-time SST of area 1° in latitude by 1° in longitude. The monthly means have been calculated by taking averages of weekly observations for all weeks falling totally, or for the most part, within the target month. These are MCSST AVHRR data and are available from 1982 when NOAA-7 was launched with a split window AVHRR, and are FTP-ed on a weekly basis from NCEP to the Hadley Centre. The use of AVHRR pathfinder data has been considered but has not been analysed as yet.

2.3 TRMM Microwave Imager measurements

The TRMM (TMI) instrument is onboard the Tropical Rainfall Monitoring Mission (TRMM), a joint NASA and NASDA mission, which was launched in November 1997.

The TRMM satellite moves from west to east in an inclined orbit providing data at various local times between latitudes 40°S and 40°N. The TMI is a conical scan microwave radiometer with channels at five separate frequencies: 10.7, 19.4, 21.3, 38 and 85GFHZ and a spatial resolution of about 40km. The 10.7GHz channel is used to retrieve SST as it is insensitive to water vapour and cloud. This gives an advantage over infrared sensors as cloudy (although non-precipitating) coverage can be viewed with TMI. In addition to precipitation, the TMI does have sensitivities to sea surface roughness and so the microwave SST retrieval attempts to account for these effects. Details of the physical retrieval algorithm, which aims to derive SST to an accuracy better than 0.5K, are give in Wentz & Meissner (2000). The TMI SSTs have been retrieved as daily averaged files (version 3) from the Remote Sensing Systems (RSS) Website http://www.ssmi.com between -40 and 40 degrees latitude. The microwave derived SSTs measure at a depth of a few millimetres. It should be noted that RSS have applied bias corrections to the TMI SSTs (Wentz & Ashcroft).

2.4 Advance Microwave Sounding Radiometer measurements

The Advance Microwave Sounding Radiometer (AMSR-E) instrument is onboard the sun-synchronous AQUA satellite which was launched in May 2002. The instrument was provided to NASA by The National Space Development Agency of Japan (NASDA). Global, daily, version 3 AMSR-E products of SST, wind speed, atmospheric water vapour, cloud water and rain rate are available from http://www.ssmi.com at 0.25° spatial resolution. The ability of AMSR-E to view SST through non-precipitation clouds is a major advantage over traditional cloud-free infra-red measurements of SST. Details of the AMSR SST algorithm are given in Wentz & Meissner (2000) and the retrieved SST product has the same characteristics as TMI.

2.5 Hadley Sea-Ice and Sea Surface Temperature (HadISST1) dataset

The HadISST1 (Rayner et al, 2003) dataset is a globally complete 1° spatial resolution sea-ice and SST analysis field, produced on a monthly basis at the Hadley Centre. The SST data which contribute to HadISST1 come from ships, buoys and AVHRR. The ship and buoy data are averaged into a 1° latitude/longitude globally complete field, from which a night-time AVHRR SST field is subtracted. The difference is smoothed to create a field for which the AVHRR data can be corrected. The corrected AVHRR and in situ fields are then averaged together onto a 2° latitude/longitude grid which is reconstructed as a 1° spatial resolution field, with gaps covered by reduced space optimal interpolation (RSOI) (Kaplan et al, 1997) and sea ice fields added to produce the final HadISST1 field.

3. Methodology

(A)ATSR anomalies are produced by subtracting a daily 1-degree 61 to 90 Global Sea-Ice and Sea Surface Temperature (GISST) climatology (Parker et. al, 1995) from daily (A)ATSR skin and bulk (D2 or D3) observations at 10 arc minute resolution. These anomalies are then averaged onto a 1-degree grid, and averaged to produce global monthly mean anomalies. The TMI and AMSR-E anomalies were created by using 0.25° SSTs averaged to 1degree cells, then subtracting a 1-degree daily 61 to

90 GISST climatology. These daily anomalies are then averaged to a global monthly mean anomaly. The AVHRR and HadISST1 SST anomalies were created by the same method but using 1-degree resolution initial SST observations.

SST anomaly time-series from different sources have been plotted on the same graphs. In these cases global mean anomalies were only computed where coincident observations were available for all the SST data sources. However, there are two exceptions to this rule: in order to plot AVHRR anomaly data back to 1982 it was necessary to include all AVHRR data through the time-series, in addition to the coincident observations for the other sources. Additionally, TMI anomaly data is presented where the observations are both coincident and non-coincident with the another anomaly sources, for the latter case, this is so TMI data can be plotted in the ATSR-2 to AATSR missing data period (2001/2002) and therefore act as a reference data set to bridge the gap.

Whereas, most of the anomaly plots are presented for global mean scenarios, plots containing TMI data are only presented for SST observations within ±40° latitude due to TMI data only being available within these latitudes. Additionally, time-series are included for data within the El-nino region analysis zone, within 5°S to 5°N, and 120°W-170°W.

Satellite SST retrievals can be subject to systematic biases. The biases on the (A)ATSR retrievals, whose coefficients are derived via radiative transfer modelling, can be summarised as retrieval errors which are state dependent, and also a mean global offset which varies according to whether a D2 or D3 retrieval has been performed. These biases have been discussed more fully in DEFRA report 4a/2/03 (O'Carroll et. al, 2004).

In this report, anomaly time-series are presented for 2 scenarios: for when the (A)ATSR data has been bias corrected (to attempt to correct for the mean global offset with respect to insitu), and for when the data has not been bias corrected. The bias corrections were derived by utilising a database which contains co-located (A)ATSR and buoy SST observations. Bias statistics and validation results using this matchup database are presented in O'Carroll, 2004 and Watts, 2004. In order to evaluate the global offsets, the buoy 'bulk' SSTs were converted to a buoy 'skin' SST using the Fairall model (Fairall et al, 1997). These buoy 'skin' SST were then compared to the (A)ATSR SSTs during night-only to derive the mean global offsets. It was found that these offsets varied throughout the years, and so for the purposes of correcting the (A)ATSR anomaly plots offsets which were derived separately for each year are used, and these are presented in Table 1.

Table 1. Bias corrections: Yearly mean global offsets applied to (A)ATSR SSTs in some experiments

		D2 offset (K)	D3 offset (K)
ATSR-2	**1995**	0.19	-0.02
	1996	0.12	-0.06
	1997	0.05	-0.06
	1998	0.07	-0.08
	1999	0.04	-0.09
	2000	0.03	-0.11
AATSR	**2002**	-0.04	-0.14
	2003	-0.06	-0.21
	2004	-0.07	-0.22

A number of different experiments to plot different variations of anomaly time-series according to different SST sources, bulk/skin D2/D3 bias-corrected and un-bias corrected (A)ATSR SSTs, different regions, and whether the SST anomalies from different sources are coincident with each other. A summary of the experiments undertaken detailing the SST anomaly time-series produced are shown in Table 2. Additionally, time-series of (A)ATSR minus AVHRR and (A)ATSR minus HadISST1 are outlined in table 2 as experiments 19 and 20.

Table 2. Details of anomaly time-series produced.

Experiment	Region	Data used	Dates	Comment	(A)ATSR bias corrected
1/2	Global	(A)ATSR AVHRR HadISST1	1995-2004 1995-2004 1995-2004	All coincident observations	Yes/No
3/4	Global	(A)ATSR AVHRR HadISST1	1982-2004 1982-2004 1982-2004	(A)ATSR/HadISST1 coincident, AVHRR not coincident	Yes/No
5/6	TMI region	(A)ATSR AVHRR HadISST1 TMI	1998-2004 1998-2004 1998-2004 1998-2004	All coincident observations	Yes/No
7/8	TMI region	(A)ATSR AVHRR HadISST1 TMI	1995-2004 1995-2004 1995-2004 1995-2004	(A)ATSR/HadISST1/ AVHRR coincident, TMI not coincident	Yes/No
9/10	Global	(A)ATSR AVHRR HadISST1 AMSR-E	2002-2004 2002-2004 2002-2004 2002-2004	All coincident observations	Yes/No
11/12	Global	(A)ATSR AVHRR HadISST1	1995-2004 1982-2004 1982-2004	AVHRR/HadISST1 coincident, (A)ATSR separate	Yes/No
13/14	Southern Ocean	(A)ATSR AVHRR HadISST1	1995-2004 1995-2004 1995-2004	All coincident observations (180°W-180°E, 20°S-60°S)	Yes/No
15/16	Northern Ocean	(A)ATSR AVHRR HadISST1	1995-2004 1995-2004 1995-2004	All coincident observations (180°W-180°E, 20°N-60°N)	Yes/No
17/18	Tropical Pacific	(A)ATSR AVHRR HadISST1 TMI	1998-2004 1998-2004 1998-2004 1998-2004	All coincident observations (5°S-5°N, 170°W-120°W)	Yes/No
19/20	Global	(A)ATSR-AVHRR (A)ATSR-HadISST1	1995-2004 1995-2004	All coincident observations	Yes/No

4. Results

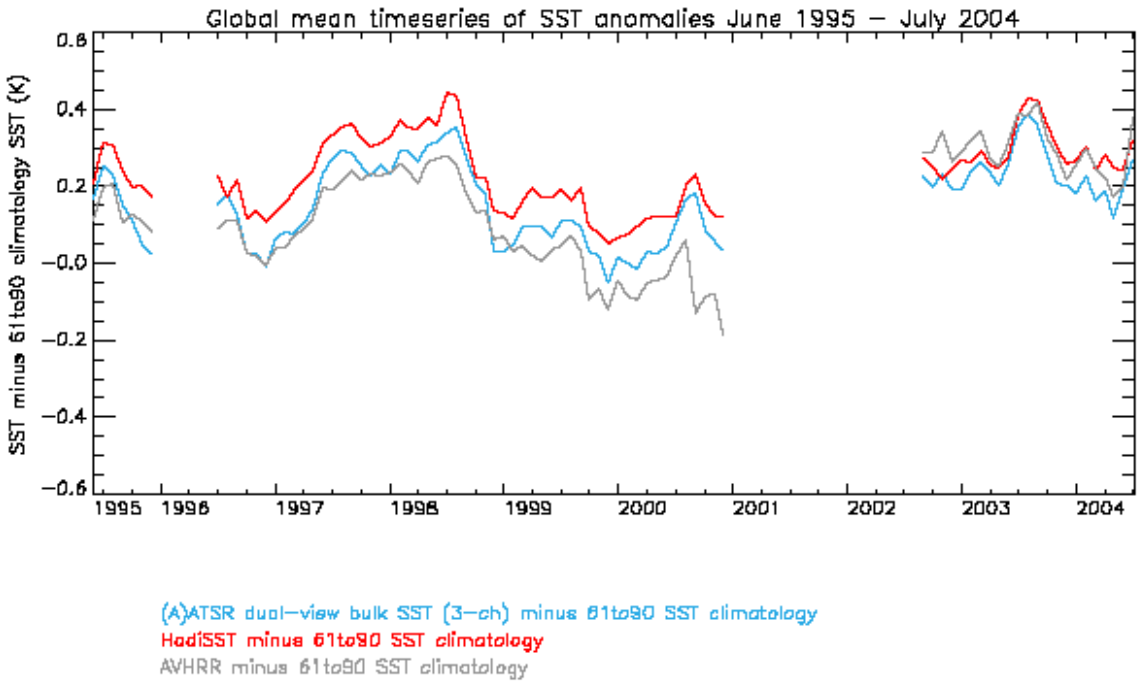
4.1 Anomaly time-series

The (A)ATSR SSTs used in experiments 1-19 are bulk (A)ATSR SSTs. These provide a better comparison to AVHRR bulk SSTs and HadISST than (A)ATSR skin SSTs at the expense of relying on the accuracy of NWP surface wind fields. The (A)ATSR data plotted are for D3 retrievals at night-time only. Further time-series for all experiments, which include the standard deviations and number of observations for each mean SST time-series are included in the Annex.

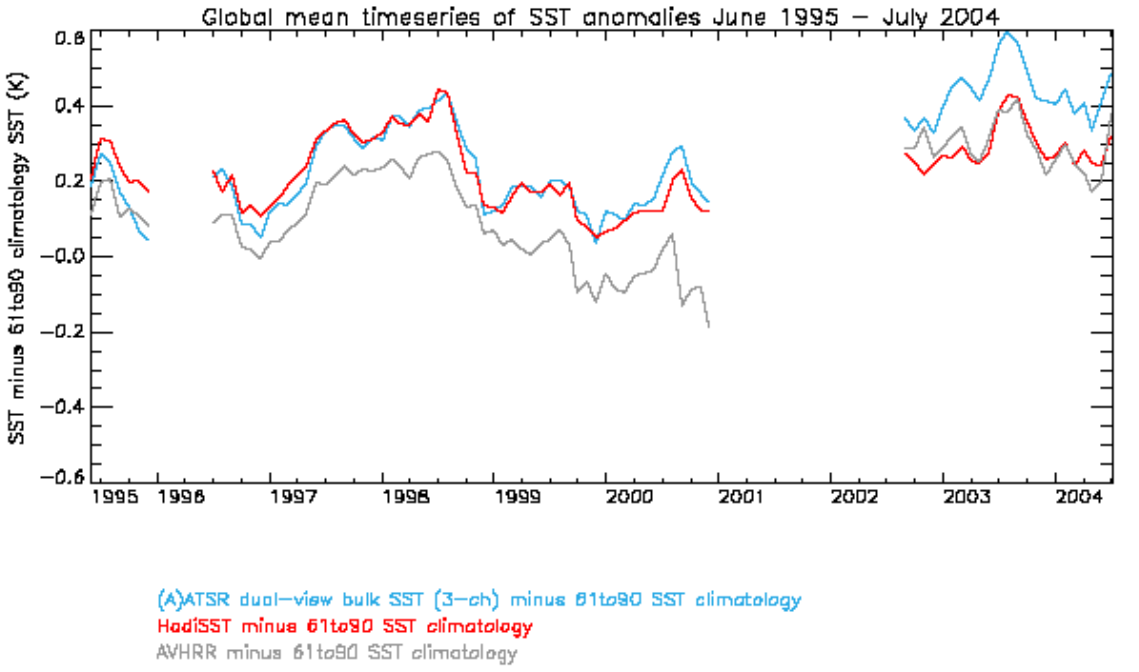
The global time-series presented in experiment 1 and 2 show that for the bias-corrected timeseries, both ATSR-2 and AATSR SSTs are cooler than HadISST, however AVHRR SSTs change from being the coolest SSTs (up to 2000), and are the warmest from 2002 onwards. For the un-bias corrected (A)ATSR timeseries in experiment 2, ATSR-2 is more similar to HadISST1 than after the bias-correction has been added. Whilst, the AVHRR SSTs are regressed to buoy SSTs, and the (A)ATSR bias correction was calculated from comparisons against buoy SSTs, it follows that the bias-correction step for the ATSR-2 SSTs would cause the SSTs to be closer to AVHRR. The un-bias corrected AATSR SSTs appear much warmer than the other SST sources, and the bias-correction step attempts to correct for this. Note the presence of the 1998 El-Nino event, which warms the global SSTs for all sensors in 1997-1998. Note that there was a decrease by around half in the model fields available in December 2002, which are used to estimate the skin-bulk temperature difference, causing a dip in the production of bulk AATSR SSTs at this time.

The global time-series presented in experiments 3 and 4 show similar data to that plotted in experiments 1 and 2, however, the AVHRR SSTs are not coincident with the other SST sources which allows AVHRR data for the missing (A)ATSR data period in 2001/2002 to be plotted, and to plot AVHRR data back to 1982. As the AVHRR data included in experiments 3 and 4 is not coincident with (A)ATSR nor HadISST1 it will include more global data leading to the wider variations in anomalies. AVHRR SSTs follow bias-corrected (A)ATSR SSTs more closely than HadISST. For the time-series plotting un-bias corrected (A)ATSR, AVHRR is cooler than both ATSR-2 and AATSR by around 0.1-0.2K. Interestingly, AVHRR SSTs are similar to HadISST for 2002- present, However from 1995 to 2000, AVHRR is cooler than HadISST.

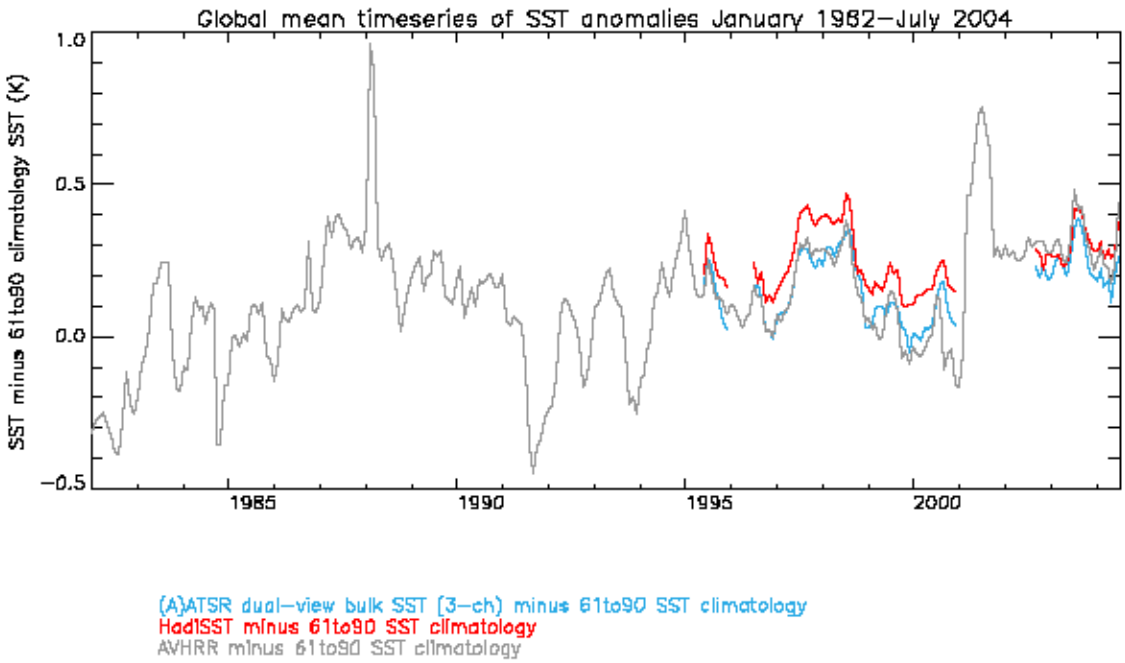
Experiment 1: Global bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident



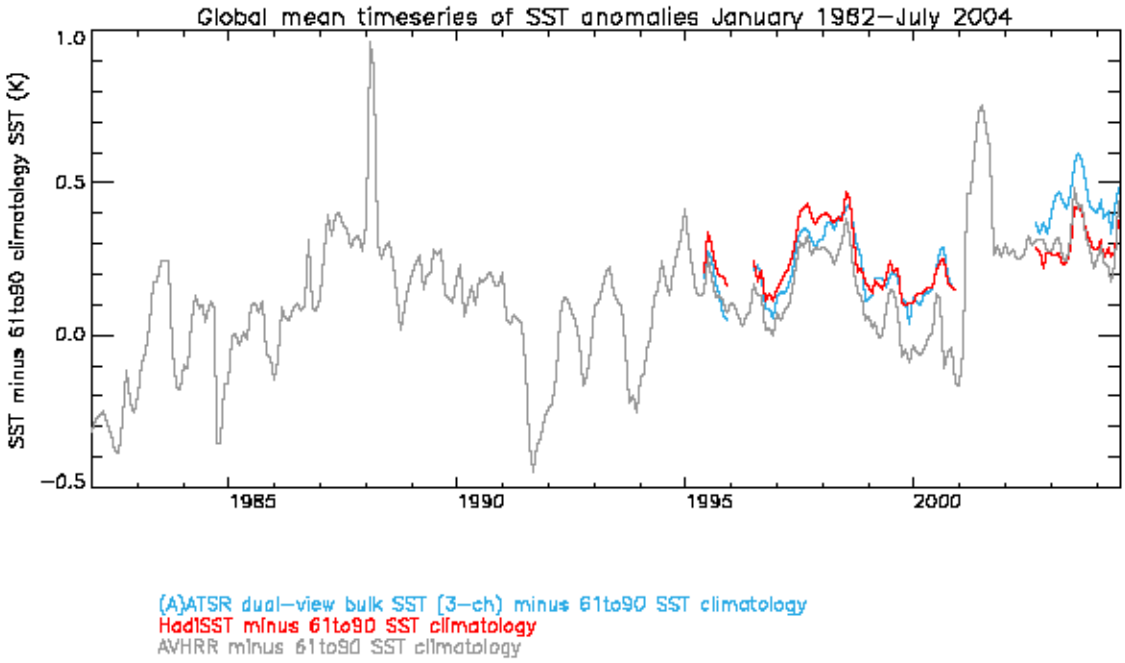
Experiment 2: Global, un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident



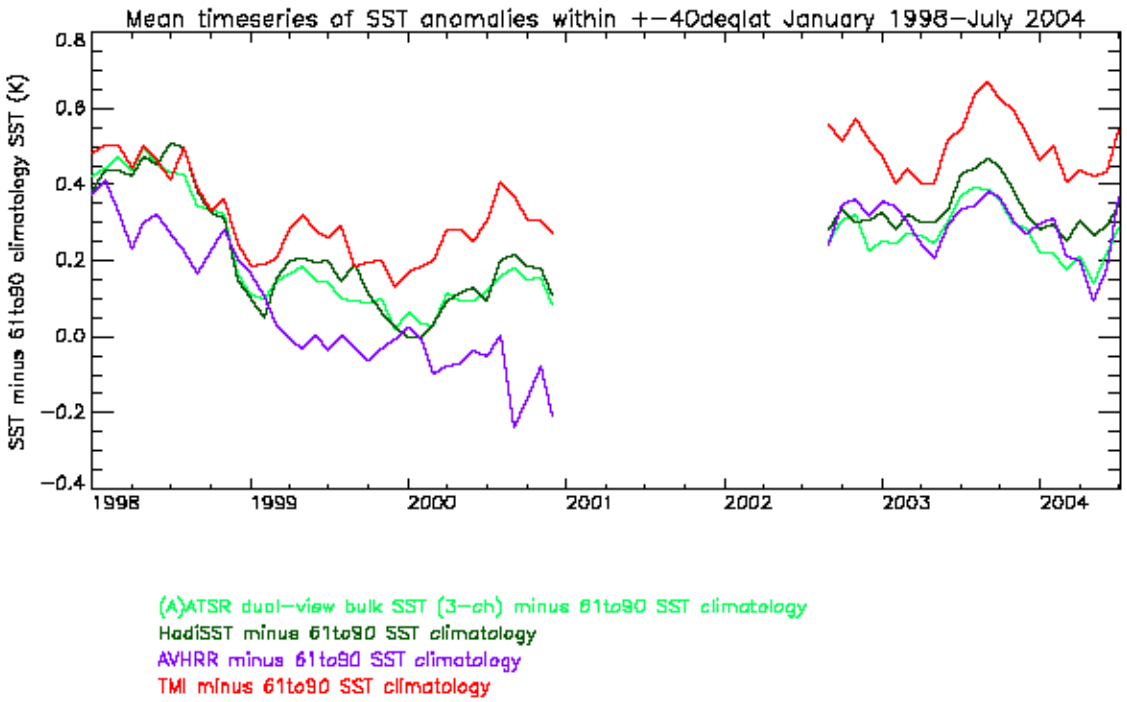
Experiment 3: Global, bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident except AVHRR



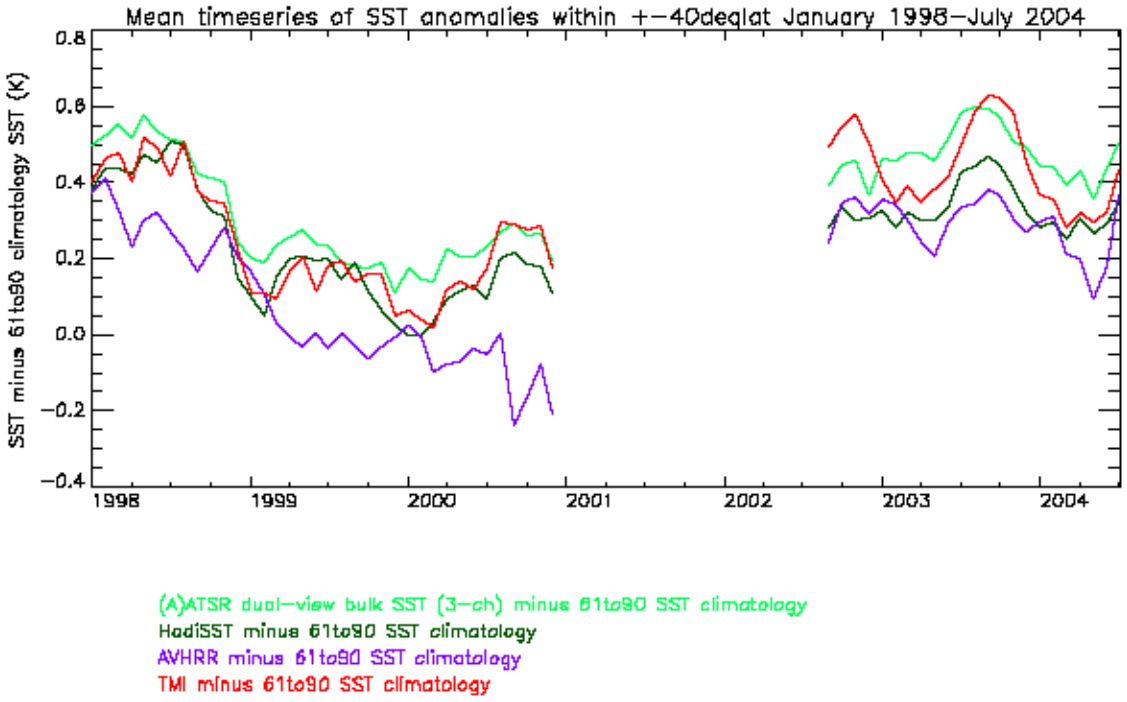
Experiment 4: Global, un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident except AVHRR



Experiment 5: Tropical, bias-corrected (A)ATSR, HadISST1, night-time AVHRR, TMI, all coincident



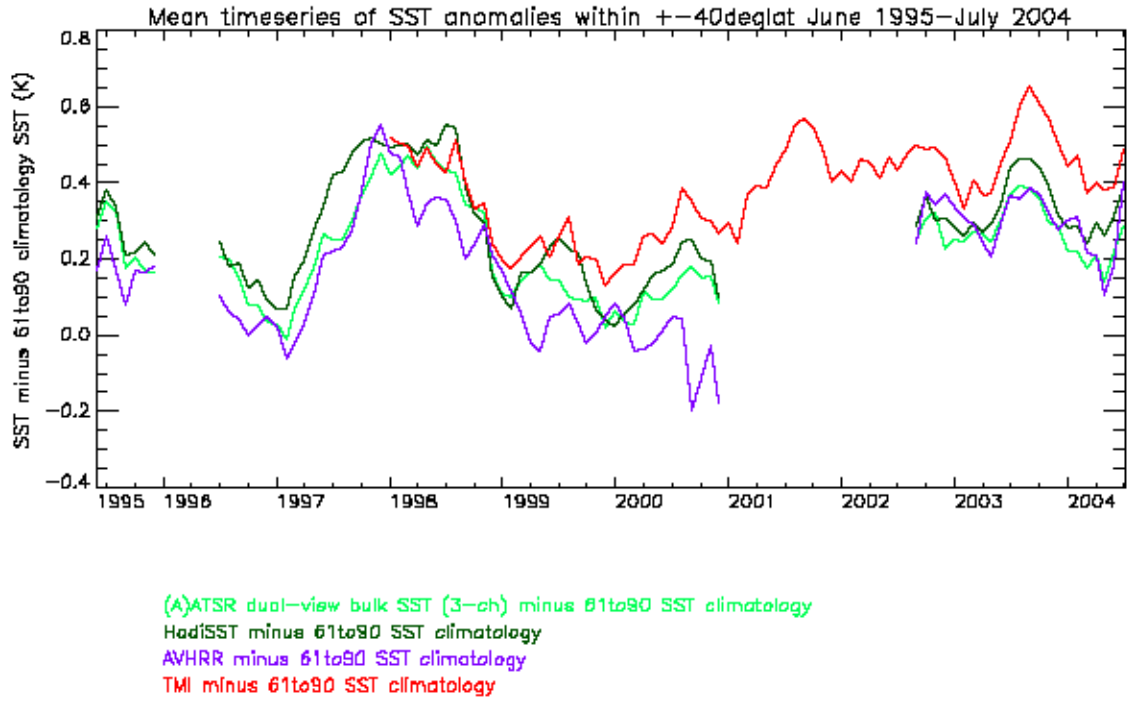
Experiment 6: Tropical, un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, TMI, all coincident



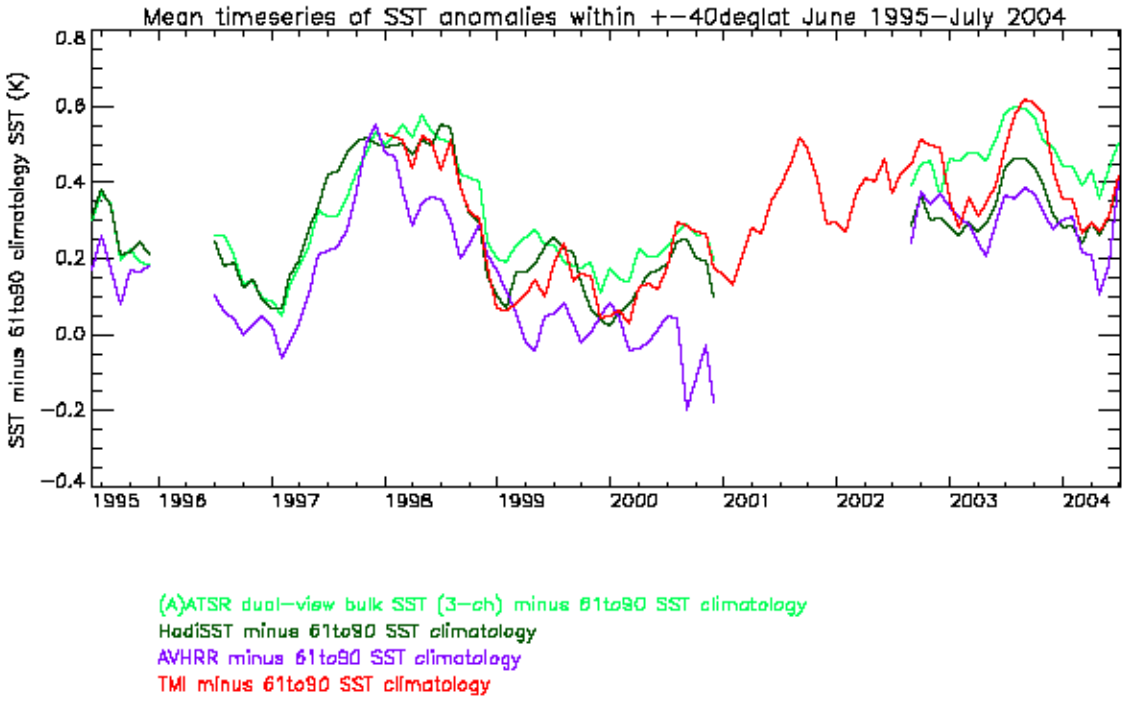
Over the TMI region (experiments 5 and 6), within latitude bounds 40ºN and 40ºS, bias-corrected (A)ATSR and HadISST1 are very similar throughout the period, although the AATSR SSTs are slightly cooler than HadISST than for ATSR-2 suggesting the AATSR bias correction may be slightly too great. AVHRR SSTs are close to bias-corrected AATSR SSTs and HadISST1 from 2002 onwards, but significantly cooler from 1998-2000. This supports the observation of inconsistency in AVHRR observed in experiments 3 and 4. Looking at the TMI anomalies, TMI SSTs are similar to the bias-corrected ATSR-2 SSTs and HadISST1 from 1998-1999, but warmer than ATSR and HadISST1 from 2000 onwards by ~0.1K, which could suggest inconsistency in the TMI SSTs. However, looking at experiments 7 and 8 which include un-coincident TMI anomalies to transverse the 2001/2002 (A)ATSR missing data period, a similar pattern is seen as for experiments 5 and 6 where ATSR-2 SSTs anomalies are similar to TMI SST anomalies up to 2000, then TMI is warmer than ATSR-2/AATSR there-after.

The time-series in experiments 9 and 10 show global (A)ATSR SSTs, HadISST1, AVHRR, and AMSR-E SSTs, where they are all coincident observations. Two things should be noted from these time-series. Firstly, the AMSR-E SSTs seem to have a lag in the anomaly pattern so the data should be treated with caution, especially since the data has been bias-corrected with an unknown and unpublished method. Secondly, the bias-correction applied to the AATSR SSTs is effective in bringing the bulk SSTs to a more comparable level to the AVHRR bulk SSTs and HadISST1, although it seems to have over-compensated very slightly.

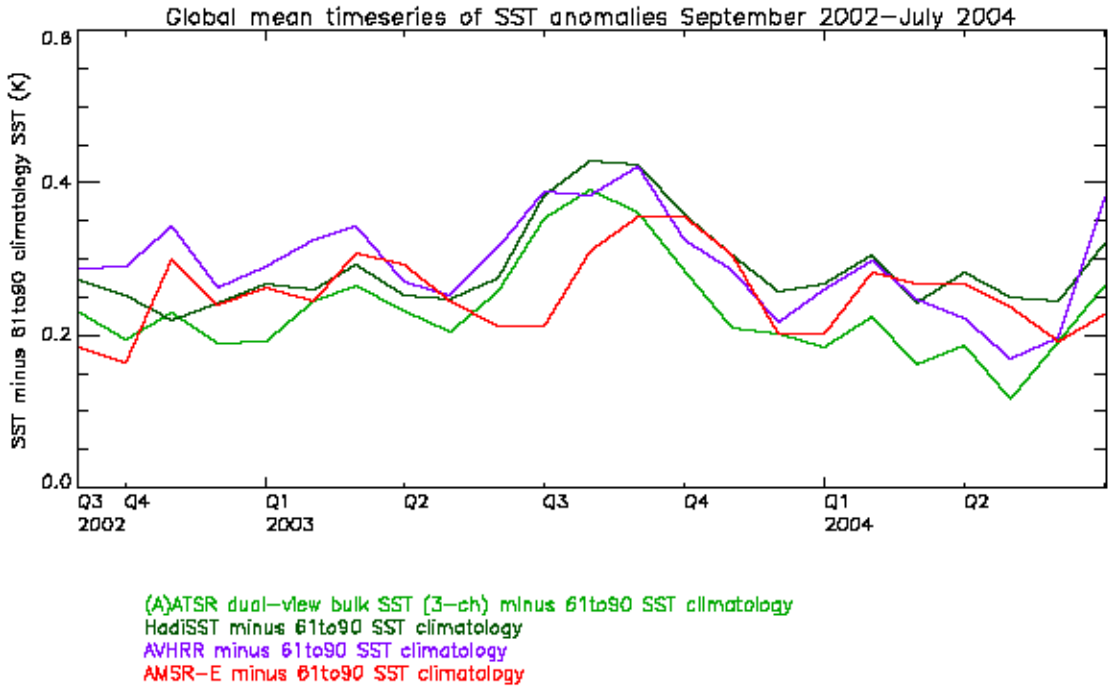
Experiment 7: Tropical, bias corrected (A)ATSR, HadISST1, night-time AVHRR, TMI, all coincident except TMI



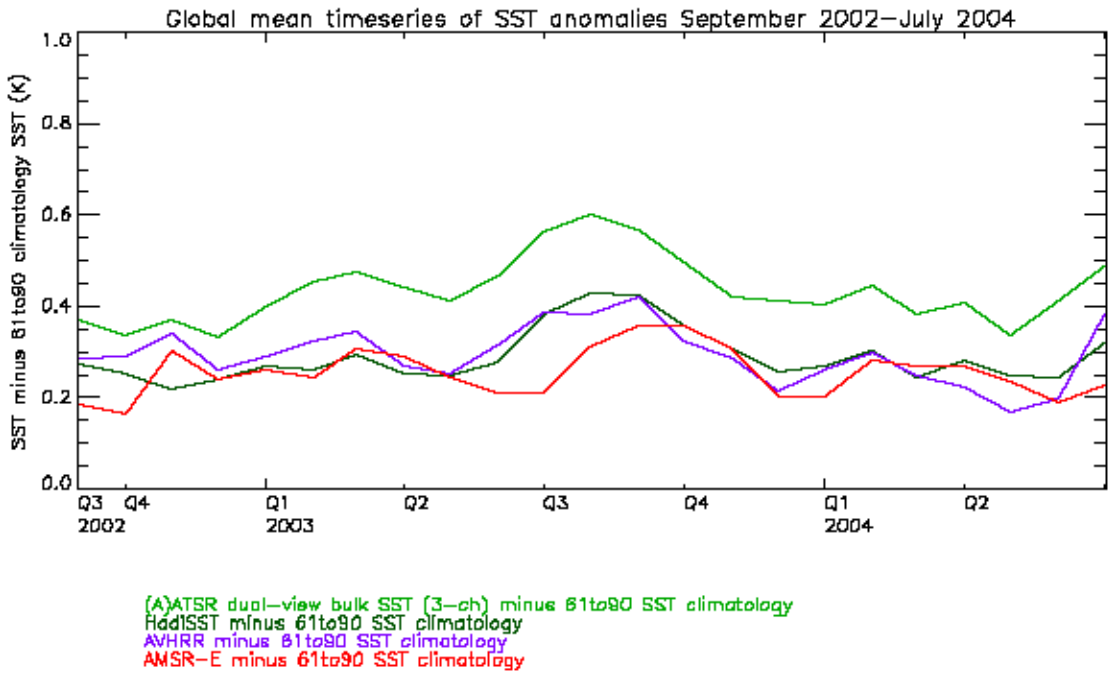
Experiment 8: Tropical, un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, TMI, all coincident



Experiment 9: Global, bias-corrected (A)ATSR, HadISST1, night-time AVHRR, AMSR-E, all coincident



Experiment 10: Global, un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, AMSR-E, all coincident



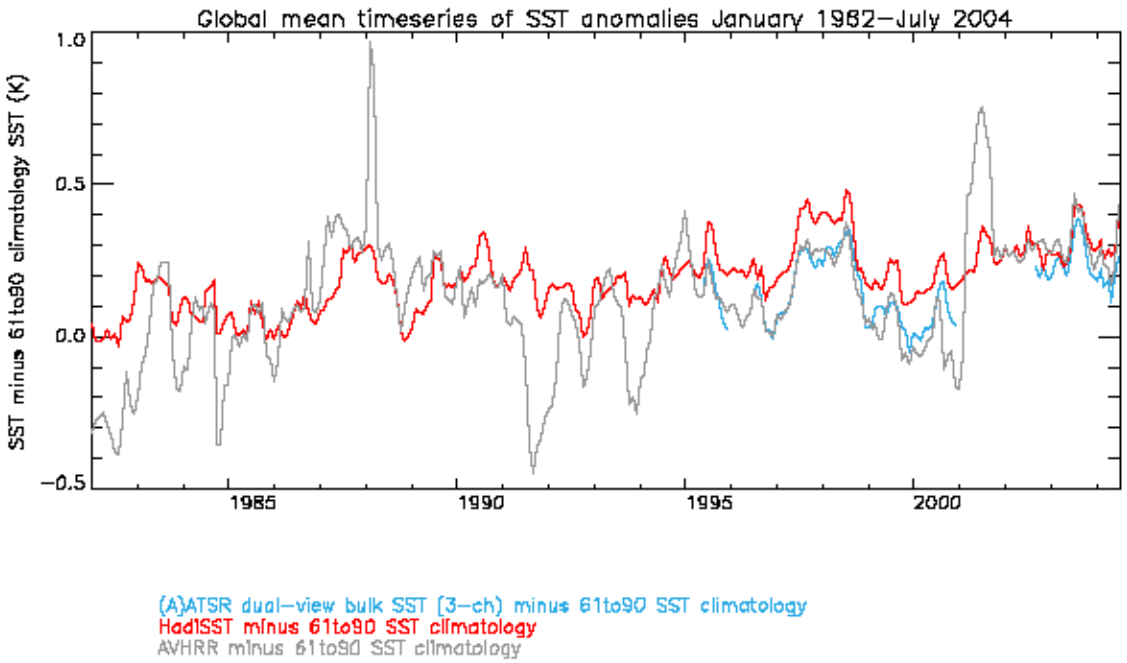
The anomaly time-series presented in experiments 11 and 12 show results for where HadISST1 and AVHRR are coincident, but (A)ATSR is not. The AVHRR line clearly shows the cooling effect of the 1982 El Chichon and 1991 Pinatubo volcanic eruptions, where vast amounts of aerosol were injected into the Strasophere. The HadISST1 anomalies are not affected by this cooling. (A)ATSR data is not available for these events, although ATSR-1 data for 1991 may be in the near future. However, we would expect (A)ATSR SST retrievals to be less effected by the presence of stratospheric aerosol due to the use of aerosol-robust SST retrieval coefficients as described in Merchant & Harris, 1999. Overall, the plots show that HadISST1 had a good agreement with the median trend of AVHRR (which is subject to wider fluctuations) up to 1995, then AVHRR is cooler than HadISST until 2002 from when they are once again similar.

Experiments 13 and 14 show anomaly time-series for a region in the Southern Ocean from 180 °W-180°W, 20°S-60°S, where all the observations presented are coincident. The AVHRR SST anomalies are seen to be much cooler than HadISST and (A)ATSR by up to 0.5K, suggesting AVHRR is perhaps affected by cloud contamination in this region. Experiments 15 and 16 show similar plots but for the region in the Northern Oceans of 180°W-180°E, 20°N-60°N. For these time-series, HadISST anomalies are shown to be in-between bias-corrected ATSR-2 and AVHRR, however, HadISST anomalies are very similar to the AATSR SST anomalies.

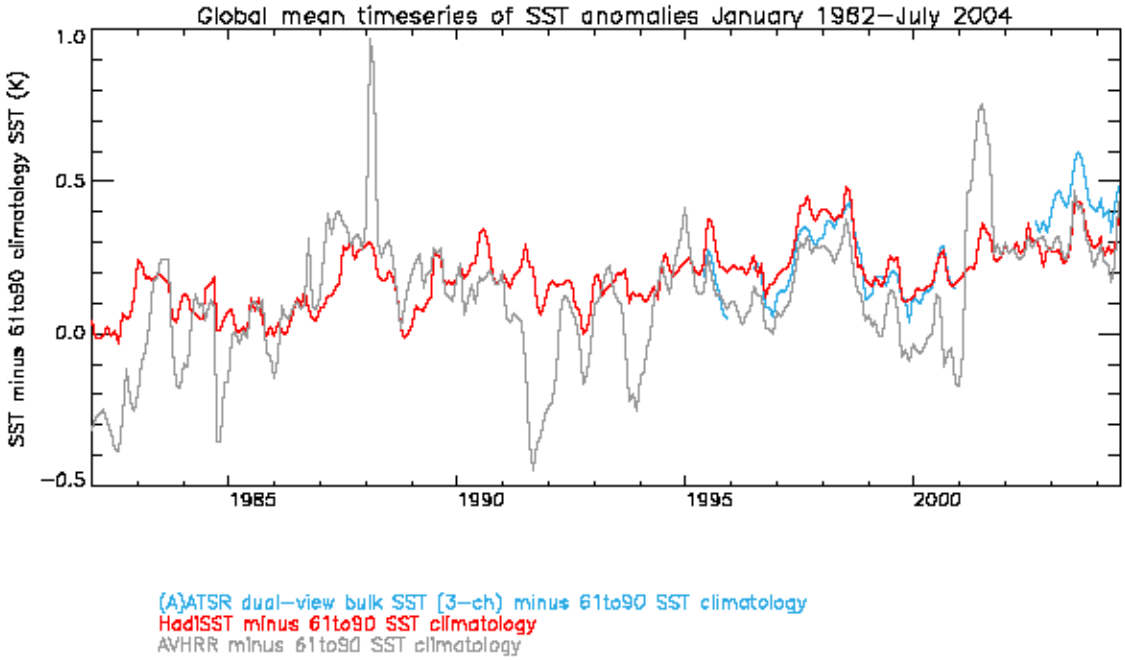
Experiments 17 are 18 show time-series for the Tropical Pacific (120°W-170°W, 5°S-5°N). The time-series is shown for all coincident observations, hence the missing data period in 2001/2002 due to the lack of (A)ATSR data, and the time-series is

presented from 1998 due to this being the start of availability of TMI SST data. The effect of the 1998 El-Nino is clearly seen. Additionally there is a lesser warming even in late 2002.

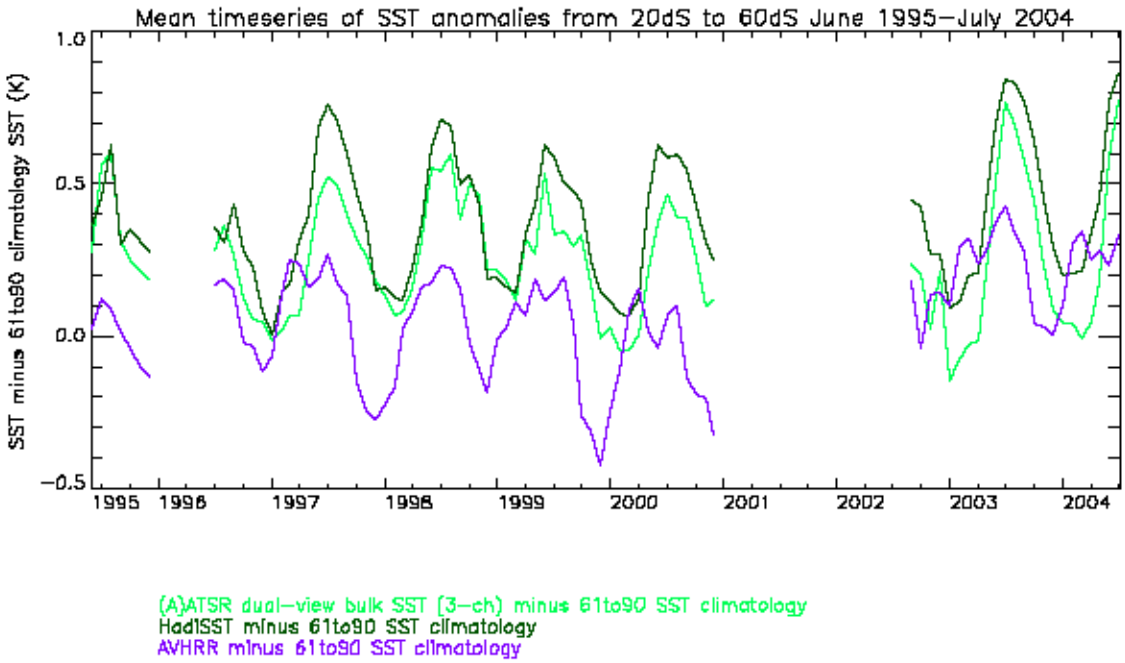
Experiment 11: Global, bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident except (A)ATSR



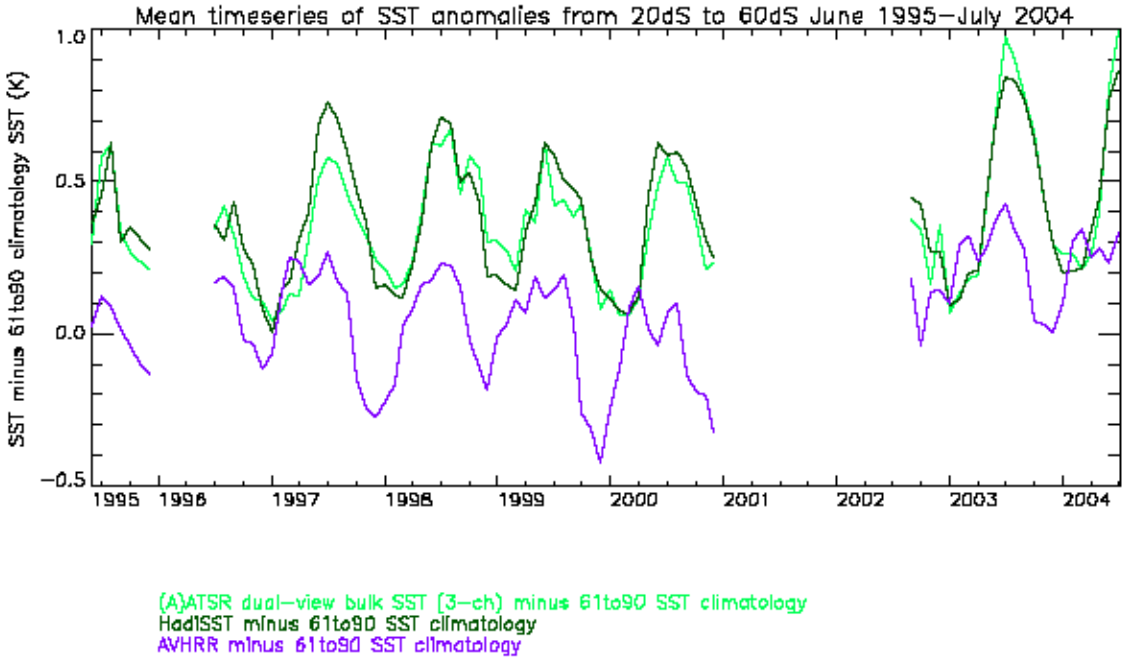
Experiment 12: Global, un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident except (A)ATSR



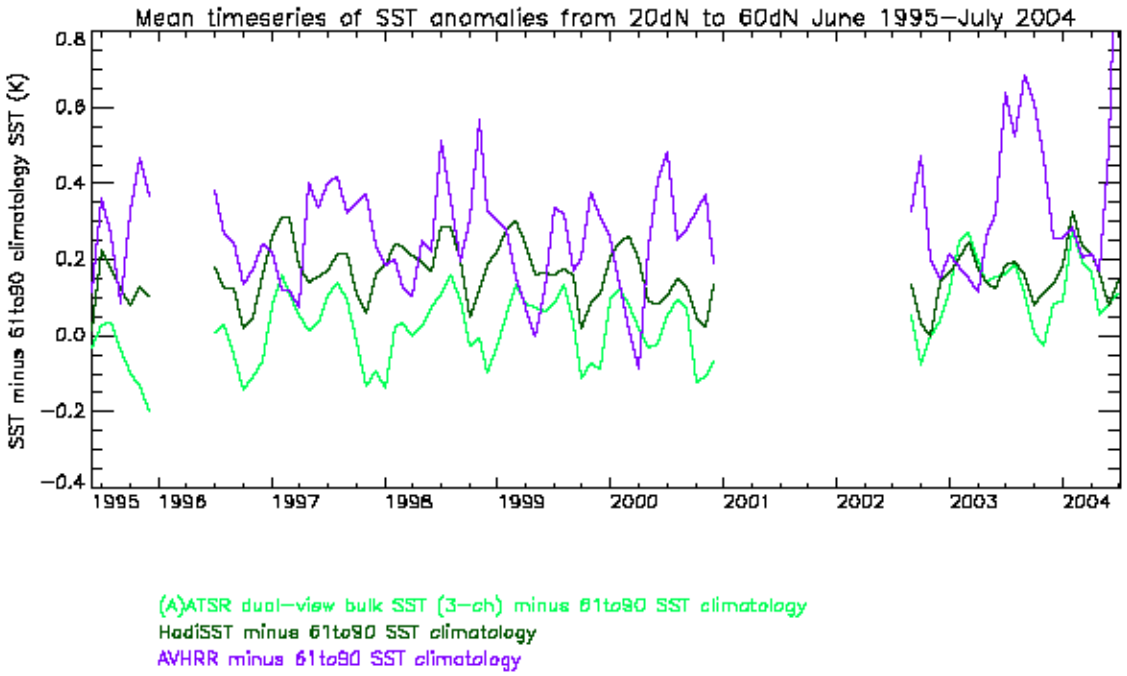
Experiment 13: Southern Ocean (180°W-180°E, 20°S-60°S), bias-corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident



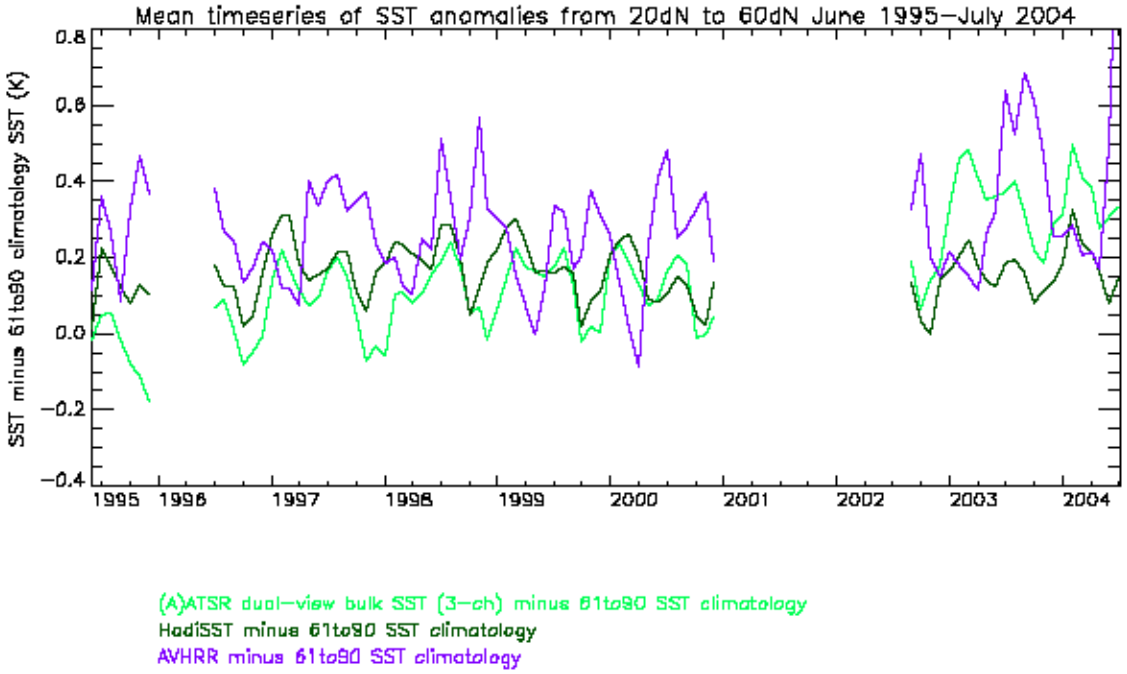
Experiment 14: Southern Ocean (180°W-180°E, 20°S-60°S), un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident



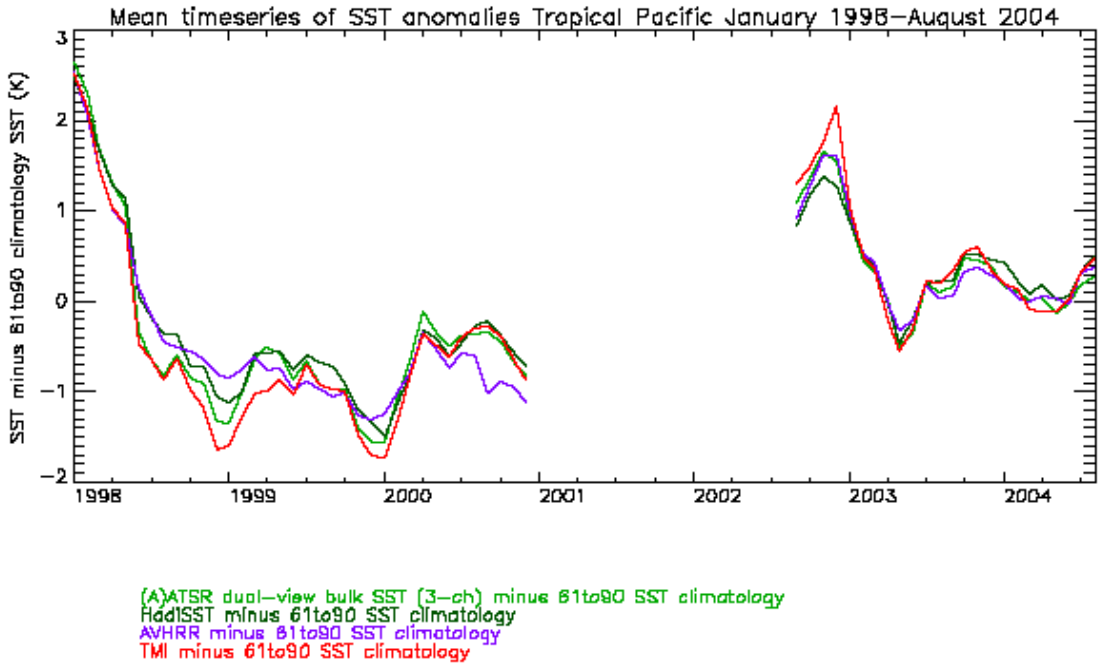
Experiment 15: Northern Ocean (180°W-180°E, 20°N-60°N), bias-corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident



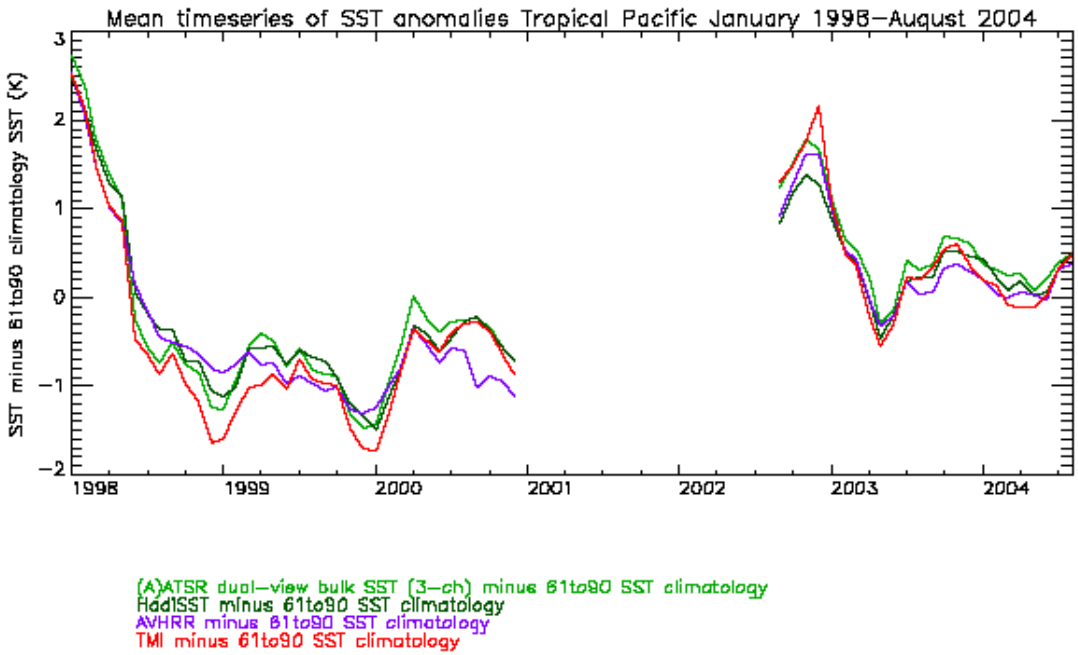
Experiment 16: Northern Ocean (180°W-180°E, 20°N-60°N), un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, all coincident



Experiment 17: Tropical Pacific 5S-5N, 120W-170W, bias-corrected (A)ATSR, HadISST1, night-time AVHRR, TMI, all coincident

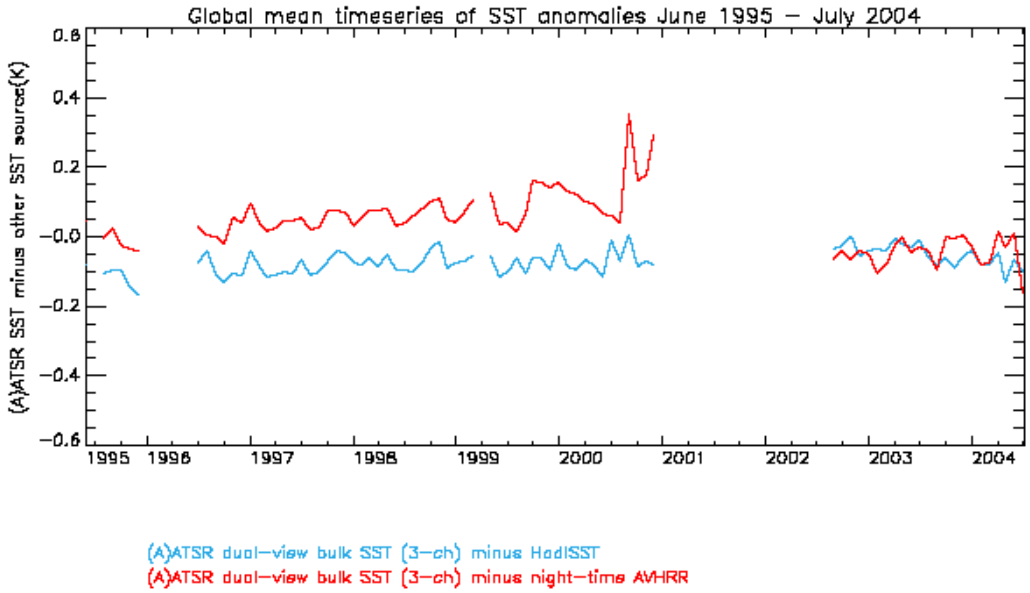


Experiment 18: Tropical Pacific 5S-5N, 120W-170W, un-bias corrected (A)ATSR, HadISST1, night-time AVHRR, TMI, all coincident

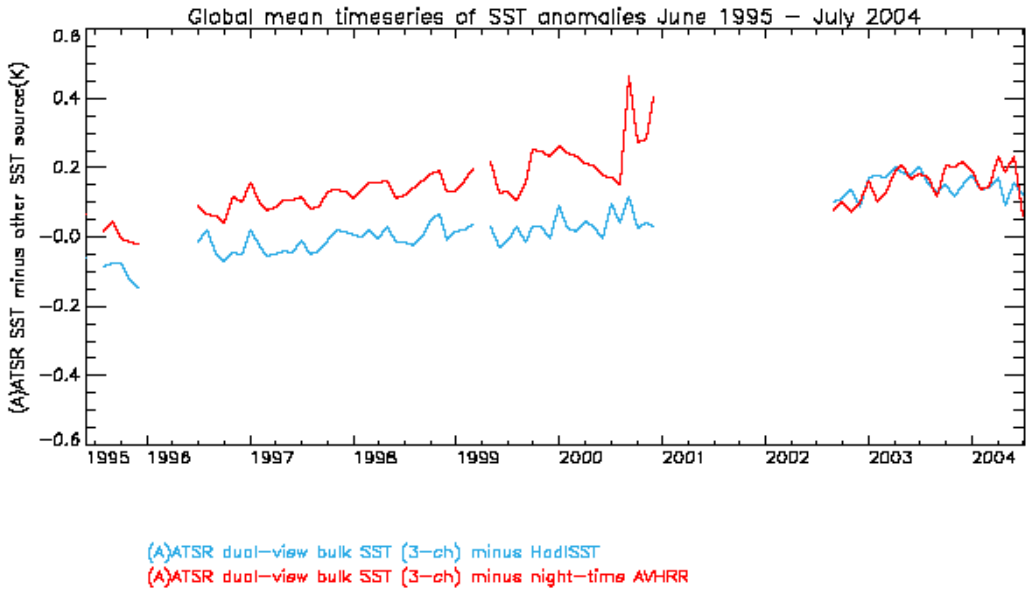


Experiments 19 and 20 show time-series of bias corrected and un-bias corrected (A)ATSR minus HadISST1 and night-time AVHRR. All observations are coincident, hence the gaps within ATSR missing data periods. Global HadISST SSTs are seen to be warmer than AVHRR up to the end of 2000, but then similar to AVHRR for the AATSR period from 2002 onwards. Similar characteristics between AVHRR and HadISST1 are also seen in experiments 1-8.

Experiment 19: Time-series of bias-corrected (A)ATSR minus HadISST1 and bias-corrected (A)ATSR minus night-time AVHRR, all coincident



Experiment 20: Time-series of un-bias corrected (A)ATSR minus HadISST1 and un-bias corrected (A)ATSR minus night-time AVHRR, all coincident



4.2 Global maps of SST anomalies for July 2003

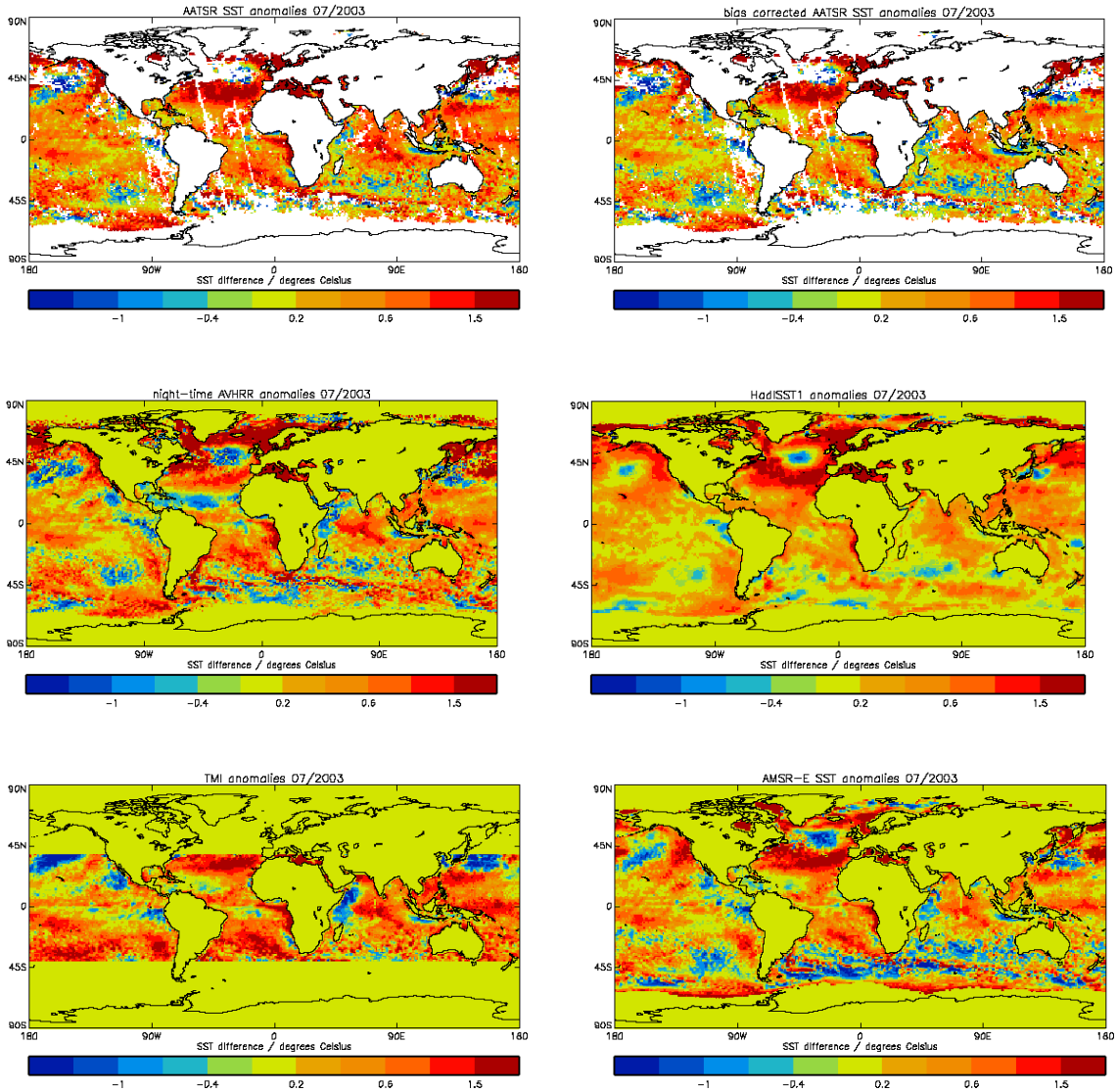
July 2003 is noted for the event of a significant Saharan dust plume outbreak over the tropical Atlantic (J. Haywood, personal communication, 2004). Mineral dust can significantly affect satellite retrievals of SST, making July 2003 an interesting month to study global SST anomalies from different satellite sensors and other SST datasets.

Experiment 21 shows the global SST anomalies for un-bias corrected AATSR, TMI, HadISST1, night-time un-bias corrected AVHRR and AMSR-E for July 2003. These anomaly maps have been constructed using differences of monthly mean SSTs over 1 degree spatial resolution.

All images in experiment 21 show similar characteristics in the distribution of maximum and minimum anomaly differences, although there are more subtle differences in the plots. The AVHRR SSTs display cooler SSTs in the Eastern Tropical Atlantic likely to be due to the presence of Saharan dust, whilst the TMI and AATSR plots show warmer SST anomalies in this region. The dual-view capability of AATSR enables improved SST retrieval in such regions. The HadISST1 anomalies also show no cool SSTs in this region.

The TMI SST anomaly map shows cool SSTs in the Western tropical Atlantic, also seen in the AMSR SST anomaly map, in a region known for developing tropical cyclones. The ability of TMI to view the sea surface through non-precipitating clouds would enable the cooler SSTs present after a tropical storm to be viewed, whereas AATSR and HadISST1 anomalies do not appear to receive this signal. The AVHRR anomalies are also cool in this region, but they may still be affected by dust plumes which have traversed the Atlantic. All the SST sources view a warm anomaly around the Gulf Stream (TMI is not in range). However, HadISST1 and AVHRR view a cool anomaly to the north of this warm anomaly which is not seen in the AATSR plot due to the lack of data. It may be that the stringent AATSR cloud detection scheme is wrongly assigning pixels in this region to cloud due to the high spatial variation of SSTs here causing the spatial difference cloud detection test to be tripped.

Cool anomalies in the North and South Pacific are observed by all SST sources, although the shape and extent seems to be smoothed by HadISST1.



Experiment 21 Global SST anomalies for July 2003 for different SST sources (top left: un-bias corrected (3ch night) AATSR; top right: bias corrected (3ch night) AATSR; middle-left: night-time un-bias corrected AVHRR; middle right:-HadISST1; bottom-left: TMI; bottom-right: AMSR-E)

5. Conclusions

Using AVHRR SST anomalies as a reference data-set, HadISST is warmer than AVHRR prior to the year 2000, and they show similar anomalies from 2002 to 2004. AVHRR SST anomalies are consistently cooler than un-bias corrected (A)ATSR throughout. After bias-correction of the (A)ATSR SSTs, the AVHRR anomalies are very similar to the ATSR-2 anomalies, however, the AATSR anomalies are slightly less than the AVHRR anomalies suggesting the AATSR D3 bias correction may be overcompensating, whilst the ATSR-2 D3 bias correction is optimal.

Using TMI SST anomalies as a reference data-set, it can be seen that TMI SST anomalies are similar to bias-corrected ATSR-2 SST anomalies up to the end of 1999,

but slightly cooler than bias-corrected ATSR-2/AATSR SST anomalies there-after. Experiment 8 shows that TMI is much cooler than un-bias corrected AATSR (except for a peak in anomalies in Autumn 2003), indicating the large bias correction (~-0.2K) that AATSR needs. However, these results indicate that perhaps the bias-correction derived is slightly too large. This is re-iterated by the results shown in experiment 9 and 10, comparing with HadISST and AVHRR SST anomalies, suggesting the bias-correction presently used is too large by up to 0.03K. It must be remembered that the (A)ATSR bias correction is derived by comparisons against buoy SSTs which have their own errors of up to 0.5K (Emery et. al, 2001).

From the AATSR skin SST dual-view 2-channel night (D2n) anomalies shown in the Annex, it can be seen that bias-corrected ATSR-2 SST anomalies are around 0.1K cooler than AVHRR, which is expected due to the skin effect (Horrocks et al, 2003). HadISST anomalies are warmer than both AVHRR and ATSR-2 up to 2000. However, bias-corrected AATSR is cooler than AVHRR, but by approximately the same amount as that by which ATSR-2 is cooler than HadISST. Therefore using HadISST as a reference, bias-corrrected ATSR-2 and AATSR SST anomalies are consistent throughout the time period. Standard deviations for HadISST anomalies are consistently lower than for AVHRR and (A)ATSR anomalies likely to be due to the GISST climatology being compiled in the same way as HadISST.

The AMSR-E SST anomalies display a lag in their pattern behind the other SST sources (AATSR, AVHRR and HadISST1) indicating problems with the AMSR-E SSTs. No similar lag is observed in the TMI SST anomalies at present. More confidence should be given to the infra-red derived SSTs than the microwave SSTs.

The regional studies show that in the Southern Oceans AVHRR SST anomalies are much cooler than the HadISST1 and (A)ATSR SST anomalies, perhaps indicating a problem with the AVHRR cloud screening process. AVHRR SST anomalies are also shown to be affected by stratospheric aerosol, whilst HadISST1 is not. The analysis in the Tropical Pacific shows clearly the effect of the 1998 El-Nino, which from other experiments is also shown to warm global SST anomalies. Experiment 21 also shows that (A)ATSR is not affected by desert dust unlike AVHRR.

It is difficult without the addition of ATSR-1 SST anomaly data from 1991-1995 to assess the possibility of any trends in the ATSR data, although the time-series indicate the possibility of warming trends between 0.1-0.2K per decade.

This study highlights a requirement for ATSR-1 data from 1991 – 1995 in order to extend the time-series to at least 13 years. ATSR-1 data are expected to be supplied by the Rutherford Appleton Laboratories by March 2005 at which point the time-series presented in this report will be updated to show the complete time-series for (A)ATSR. Additionally, ATSR-2 data from 2002 is required in order to study the ATSR-2/AATSR overlap period.

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7. Acknowledgements

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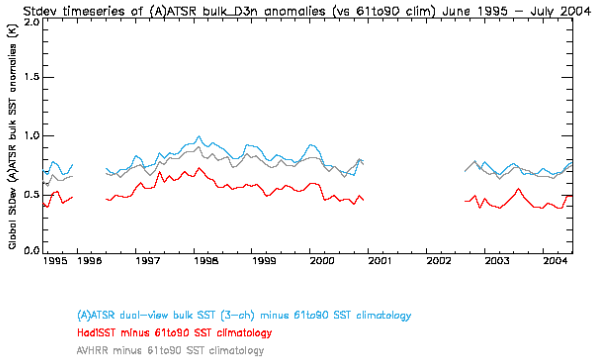
AMSR-E data are produced by Remote Sensing Systems and sponsored by the NASA Earth Science REASoN DISCOVER Project and the AMSR-E Science Team. Data are available at www.remss.com.

TMI data are produced by Remote Sensing Systems and sponsored by the NASA Earth Science REASoN DISCOVER Project. Data are available at www.remss.com.

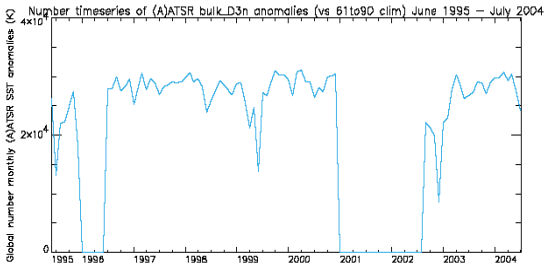
Annex: Further time-series in support of experiments 1 to 2

Experiment 1: bias-corrected (A)ATSR, AVHRR, HadISST1, 1995-2004, all coincident

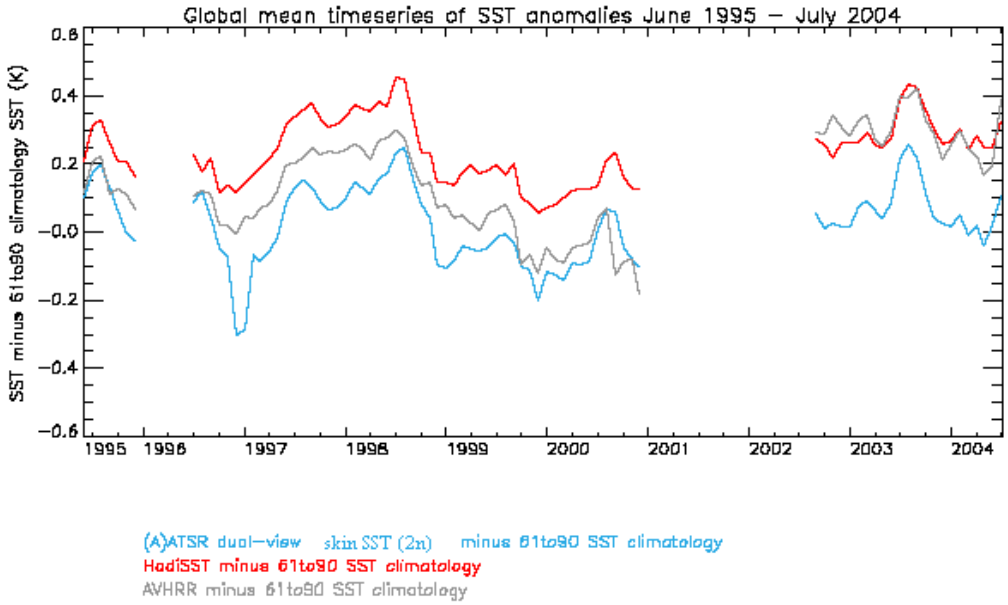
Bulk (D3n) standard deviation:



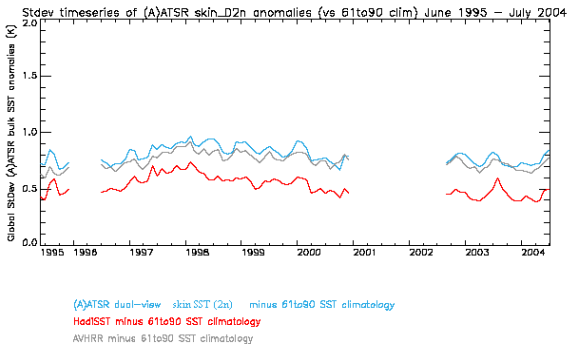
Bulk (D3n) number of observations:



Skin (D2n) mean SST anomaly:



Skin (D2n) standard deviation:



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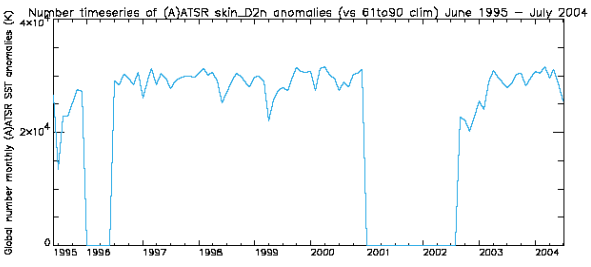

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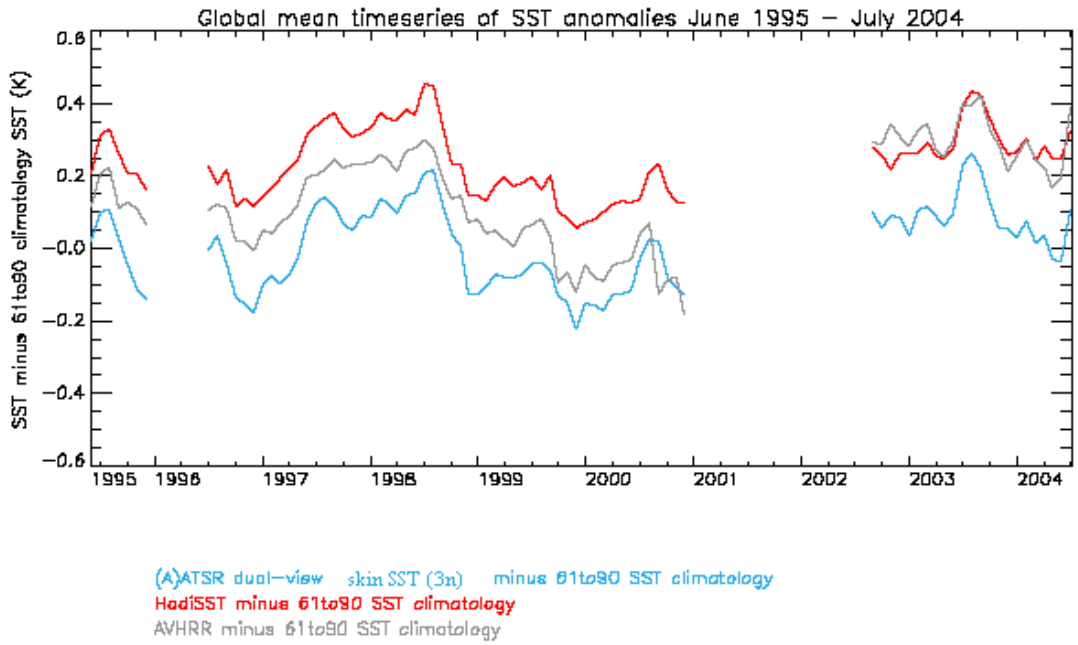

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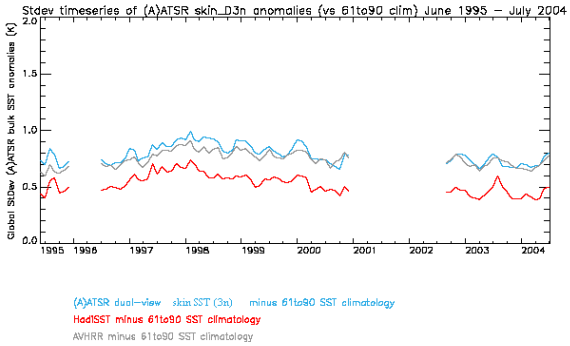

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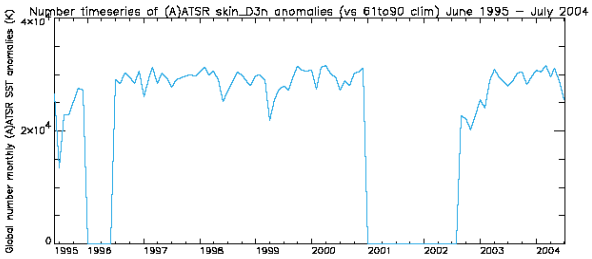
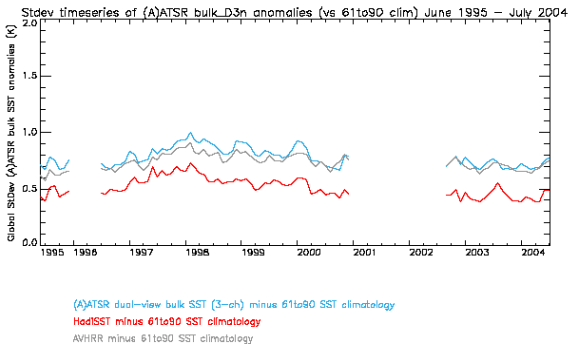


Experiment 2: un-bias corrected (A)ATSR, AVHRR, HadISST1, 1995-2004, all coincident

Bulk (D3n) standard deviation:



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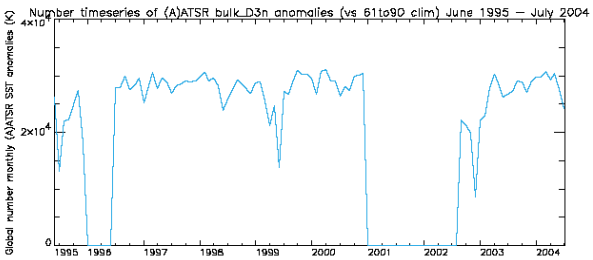
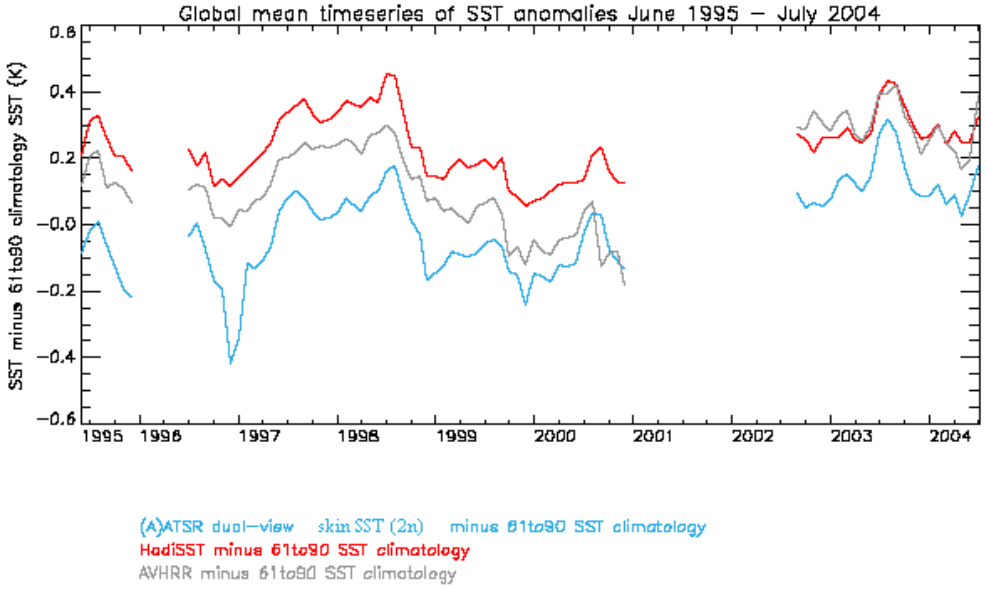
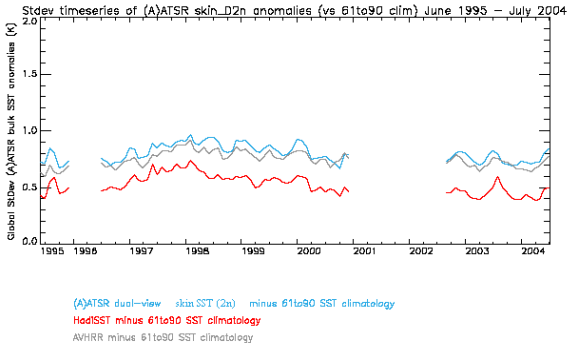


Skin (D2n) mean SST anomaly:



Skin (D2n) standard deviation:



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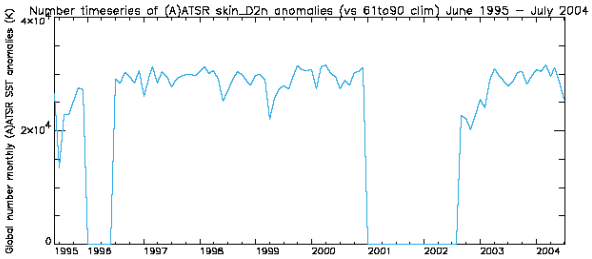

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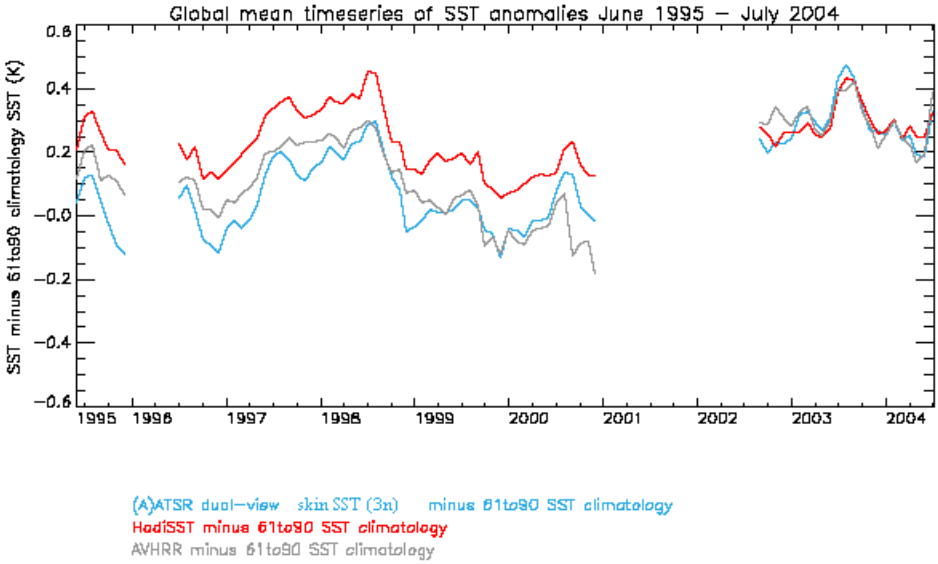
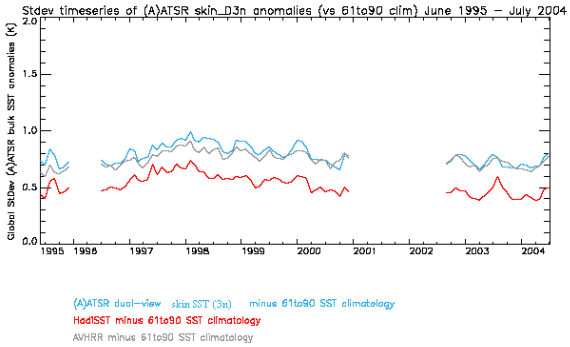
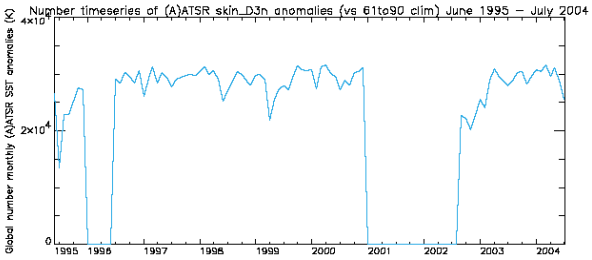


Skin (D3n) standard deviation: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